CLAIMS

1. A method of chemically treating a surface of a workpiece, comprising:

exposing the workpiece to a gaseous atmosphere containing a transmission gas that is substantially nonattenuating to preselected wavelengths of electromagnetic radiation;

providing a flow of a gaseous constituent over the surface of the workpiece;

directing a beam of said electromagnetic radiation into said gaseous atmosphere, said beam converging in said flow in close proximity to the surface of the workpiece, but spaced a finite distance therefrom, to dissociate said gaseous constituent to produce a high flux of activated reactive species; and

reacting said activated reactive species with the surface of the workpiece.

2. The method of claim 1, wherein said activated reactive species is selected from the group consisting of the noble gases, nitrogen, hydrogen, oxygen, and combinations thereof.

3. The method of claim 1 wherein the activated reactive species is selected from the group consisting of F, CF_3, CF_2, CF, NF_2, NF, Cl, O, BCl_2, BCl, FCO, and combinations thereof.

4. The method of claim 1 wherein the gaseous constituent to be dissociated is selected from the group consisting of O_2, O_3, CCl_4, BCl_3, CDF_3, CF_4, SiH_4, $CFCl_3$, F_2CO, $(FCO)_2$, SF_5NF_2, N_2F_4, CF_3Br, CF_3NO, $(CF_3)_2CO$, CF_2HCl, CF_2HBr, CF_2Cl_2, CF_2Br_2, CF_2CFCl, CF_2CFH, $CF_2CF_2CH_2$, NH_3, CHF_3, fluorohalides, halocarbons, and combinations thereof.

5. The method of claim 1 wherein the workpiece comprises a semiconductor substrate.

6. The method of claim 1 wherein the activated reactive species is reacted with the surface of the workpiece to produce etching of the workpiece.

7. The method of claim 1 wherein the surface of the workpiece is coated with a layer of photoresist and the reactive species is reacted with the photoresist to effect removal thereof.

8. The method of claim 1 wherein the activated reactive species is reacted with the surface of the workpiece to effect cleaning of foreign material located thereon.

9. The method of claim 1 wherein said electromagnetic radiation is ultraviolet radiation.

10. The method of claim 1 wherein said finite distance is less than a few mean-free-path lengths of said gaseous reactive species.

11. The method of claim 1 further comprising expanding a cross sectional dimension of said converging beam of electromagnetic radiation to produce a scanning line at least as wide as the largest breadth of the workpiece.

12 The method of claim 1 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness of less than about 10mm.

13 The method of claim 1 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness that is at least large enough to accommodate said finite distance.

14. The method of claim 1 wherein said transmission gas occupies a majority of said gaseous atmosphere and said flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer occupying a minority of said gaseous atmosphere.

15. A method of chemically treating a surface of a semiconductor substrate comprising:

providing the substrate to a chamber;

providing a gaseous atmosphere containing a transmission gas in said chamber, said transmission gas is substantially nonattenuating to preselected wavelengths of electromagnetic radiation;

providing a laminar flow of a gaseous constituent over the surface of the substrate;

directing a beam of said electromagnetic radiation into said gaseous atmosphere, said beam converging in said laminar flow to provide maximum beam energy in close proximity to the surface of the substrate, but spaced a finite distance therefrom, to dissociate said gaseous constituent and produce a high flux of activated reactive species; and

reacting said activated reactive species with the surface of the substrate.

16. The method of claim 15 further comprising providing optical elements to impart to said beam a width at the convergence of said beam.

17. The method of claim 16 wherein said width is from about 3 to about 15 millimeters.

18. The method of claim 15 wherein said beam energy is in the range of about 100 to about 5000 mJ/cm^2.

19. The method of claim 15 further comprising directing said beam of electromagnetic radiation from a laser source through a transparent window of said chamber into said gaseous atmosphere.

20. The method of claim 19 wherein said transparent window is a window selected from the group consisting of quartz, sapphire, and zinc selenide.

21. The method of claim 15 further comprising causing relative motion between the surface and said beam to cause said beam to sweep the surface of said substrate.

22. The method of claim 15 wherein said electromagnetic radiation is ultraviolet radiation.

23. The method of claim 15 wherein said activated reactive species comprises a member of the group consisting of chlorine, fluorine, and molecules containing fluorine or chlorine.

24. The method of claim 15 further comprising controlling the energy characteristics of said beam to match absorption characteristics of said gaseous constituent to produce said high flux of said activated reactive species.

25. The method of claim 24 wherein the activated reactive species is selected to match reaction characteristics of foreign material located on the surface of the substrate.

26. The method of claim 25 wherein said foreign material comprises organic material, said activated reactive species comprises oxygen, and said beam comprises ultraviolet radiation.

27. The method of claim 25 wherein said foreign material comprises a metal oxide, said activated reactive species is selected from a group consisting of chlorine, and a chorine containing molecule, and said beam comprises ultraviolet radiation.

28. The method of claim 25 wherein said foreign material comprises silicon or silicon oxide, said reactant comprises a fluorocarbon, and said beam comprises ultraviolet radiation.

29. The method of claim 25 wherein said foreign material comprises bacteria, said reactant gas comprises oxygen, and said beam comprises ultraviolet radiation.

30. The method of claim 15 where said transmission gas is selected from the group consisting of Ar, N, He, Ne, and combinations thereof.

31. The method of claim 15 further comprising delivering a diagnostic beam of radiation to monitor said surface during said processing.

32. The method of claim 15 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness of less than about 10mm.

33. The method of claim 15 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness that is at least large enough to accommodate said finite distance.

34. The method of claim 15 wherein said transmission gas occupies a majority of said gaseous atmosphere and said flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer occupying a minority of said gaseous atmosphere.

35. A method for processing a surface of a semiconductor substrate comprising:

selecting a gaseous constituent to match reaction characteristics to chemically treat the surface of the substrate with a high flux of activated reactive species;

exposing the substrate to a gaseous atmosphere containing a transmission gas which is substantially nonattenuating to preselected wavelengths of electromagnetic radiation;

providing a laminar flow of said gaseous constituent over the surface of the substrate;

directing a beam of said electromagnetic radiation into said gaseous atmosphere, said beam converging in said laminar flow in close proximity to the surface of the substrate, but spaced a finite distance therefrom;

controlling the energy characteristics of said beam to match absorption characteristics of said gaseous constituent to dissociate said gaseous constituent and produce said high flux of activated reactive species; and

reacting said activated reactive species with the surface of the substrate.

36. The method of claim 35 further comprising providing said substrate to an evacuable chamber adapted to contain said gaseous atmosphere.

37. The method of claim 36 further comprising exhausting said gaseous atmosphere and by-products of the reaction of said reactive species with the surface of the substrate from said chamber.

38. The method of claim 36 further comprising directing said beam through a window of said chamber and into said gaseous atmosphere.

39. The method of claim 35 further comprising causing relative motion between said substrate and said beam.

40. The method of claim 39 wherein said relative motion selected from the group consisting of linear, rotational, and combinations thereof.

41. The method of claim 35 wherein said gaseous constituent is selected to result in a chemical treatment selected from the group consisting of etching, cleaning, and removing photoresist.

42. The method of claim 35 further comprising mixing a conditioning gas with said gas constituent to modify said reaction of said activated reactive species with said surface of said substrate.

43. The method of claim 35 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness of less than about 10mm.

44. The method of claim 35 wherein the flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer having a thickness that is at least large enough to accommodate said finite distance.

45. The method of claim 35 wherein said transmission gas occupies a majority of said gaseous atmosphere and said flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer occupying a minority of said gaseous atmosphere.

46. A system for chemically treating a surface of a workpiece comprising:

Sub G1 a supply of a transmission gas which is substantially nonattenuating to preselected wavelengths of electromagnetic radiation;

a supply of a gaseous constituent;

an inlet structure for exposing the workpiece to a controlled gaseous atmosphere containing said transmission gas and for providing a flow of said gaseous constituent to the surface of said workpiece; and

a radiation beam source adapted to converge in said flow in close proximity to the surface of the workpiece, but spaced a finite distance therefrom, to dissociate said gaseous constituent to produce a high flux of activated reactive species that chemically treat said surface of said workpiece.

47. The system of claim 46 further comprising optics to focus said beam.

48. The system of claim 46 further comprising a structure for causing relative motion between said surface and said beam.

49. The system of claim 46 further comprising a chamber for containing said workpiece and said gaseous atmosphere during said processing, said chamber having a window transparent to said electromagnetic radiation.

50. The system of claim 46 wherein said electromagnetic radiation is ultraviolet radiation.

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51. The system of claim 47, wherein said optics further expand a cross sectional dimension of said beam such that said beam convergence into a wide scanning beam.

52. The system of claim 46 wherein said finite distance is less than a few mean-free-path lengths of said activated reactive species.

53. The system of claim 49 wherein said chamber further comprising an exhaust pump for exhausting gas from said chamber.

54. The system of claim 46 wherein said inlet structure further comprises a nozzle connected to said supply of gaseous constituent to provide a laminar flow across the surface of the workpiece.

55. The system of claim 49 wherein said chamber further comprises a heater for heating the workpiece.

56. The system of claim 49 wherein said chamber further includes a workpiece temperature sensor for measuring the temperature of the workpiece during processing; a pressure sensor for measuring the pressure of gaseous atmosphere in the chamber during processing, and a gas sensor for monitoring the gaseous activated reactive species present in said flow.

Sub91

57. The system of claim 46 further comprising a supply of a conditioning gas for modifying the chemical reaction between said activated reactive species and said surface of said workpiece, and a mixing chamber for mixing together said gas constituent and said conditioning gas.

58. The system of claim 57 wherein said conditioning gas is selected from the group consisting of accelerants and decelerants.

59. The system of claim 46 wherein said workpiece is a semiconductor substrate.

Sub91

60. The system of claim 48 wherein said structure further includes a holder for holding said substrate during said processing.

61. The system of claim 46 wherein said inlet structure is configured to provide the flow of gaseous constituent over the surface of the workpiece in the form of a layer having a thickness of less than about 10mm.

62. The system of claim 46 wherein said inlet structure is configured to provide the flow of gaseous constituent over the surface of the workpiece in the form of a layer having a thickness that is at least large enough to accommodate said finite distance.

63. The system of claim 46 wherein said inlet structure is configured such that said transmission gas occupies a majority of said gaseous atmosphere and said flow of gaseous constituent is provided over the surface of the workpiece in the form of a layer occupying a minority of said gaseous atmosphere.

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